IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant	:Kimiaki TOSHIKIYO	Group Art Unit : 2622
Appl. No.	: 10/576,023 (U.S. National Stage of PCT/JP2004/018746	Examiner : D.A. Tejano
I.A. Filed	: December 15, 2004	Confirmation No. : 9379
For	: LIGHT-COLLECTING DEVICE AND SOLID-STATE IMAGING APPARATUS	

RESPONSE UNDER 37 C.F.R. §1.111 AND INTERVIEW SUMMARY

Commissioner for Patents
U.S. Patent and Trademark Office
Customer Service Window, Mail Stop AMENDMENT
Randolph Building
401 Dulany Street
Alexandria, VA 22314

Sir :

In response to the Office Action April 2, 2010, in which a three-month shortened statutory period for response was set to expire on July 2, 2010, Applicant respectfully requests reconsideration and withdrawal of the outstanding rejections set forth in the above-mentioned Office Action in view of the following amendments and remarks.

Amendments to the Claims are reflected in a **Listing of the Claims** beginning on page 2.
Remarks begin on page 9.

AMENDMENTS TO THE CLAIMS

This listing of claims will replace all prior versions, and listings, of claims in the current application.

LISTING OF THE CLAIMS

1. (Cancelled).

2. (Previously Presented) The solid-state imaging apparatus according to claim 9,

wherein incident light is collected in a center of a plane made of said plurality of light-transmitting films, the incident light being incident at an angle asymmetrical to a center of a plane made of said plurality of light-transmitting films.

3. (Previously Presented) The solid-state imaging apparatus according to claim 9,

wherein an amount of phase change of the incident light, $\phi(x)$, depends on a distance x in an in-plane direction and approximately satisfies the following equation,

$$\phi(x) = Ax^2 + Bx\sin\theta + 2m\pi$$

wherein θ is an incident angle of the incident light, A and B are predetermined constants, and m is a natural number.

4. (Previously Presented) The solid-state imaging apparatus according to claim 9,

wherein

$$\Delta n(x) = \Delta n_{\max}\left[\phi(x)/2\pi + C\right]$$

is satisfied, where $\Delta n_{\max}$ is a difference of refractive indices between one of said plurality of light-transmitting films and a light-incoming side medium, $\Delta n(x)$ is a difference of refractive

indices between another one of said plurality of light-transmitting films and the light-incoming side medium at a position x, and C is a constant.

5. (Currently Amended) The solid-state imaging apparatus according to claim 9,

wherein heights of said plurality of light-transmitting films are constant in a direction normal to said plurality of light-transmitting films.

6. (Previously Presented) The solid-state imaging apparatus according to claim 9,

wherein each of said plurality of light-transmitting films includes one of TiO_2, ZrO_2, Nb_2O_5, Ta_2O_5, Si_3N_4 and Si_2N_3.

7. (Previously Presented) The solid-state imaging apparatus according to claim 9,

wherein each of said plurality of light-transmitting films includes one of SiO_2 doped with B or P, that is Boro-Phospho Silicated Glass, and Teraethoxy Silane.

8. (Previously Presented) The solid-state imaging apparatus according to claim 9,

wherein each of said plurality of light-transmitting films includes one of benzocyclobutene, polymethymethacrylate, polyamide and polyimide.

9. (Currently Amended) A solid-state imaging apparatus comprising arranged unit pixels, each of which includes a light-collector and a light-receiver,

wherein said light-collector comprises:

a substrate into which incident light is incident; and

above said substrate, a plurality of light-transmitting films are formed in a region into which the incident light is incident,

wherein a light-transmitting film of said plurality of light-transmitting films forms a zone having a width which is equal to or shorter than a wavelength of the incident light,

wherein each zone shares a center point which is located at a position displaced from a center of said light-receiver, and

said plurality of light-transmitting films form an effective refractive index distribution represented by a quadratic curve expressed by a distance from a center of a corresponding one of the unit pixels,

wherein, in a unit pixel, among said unit pixels, which is located at a center of a plane on which said unit pixels are formed, a position at which an effective refractive index distribution of a corresponding light-collector represented by the quadratic curve reaches ~~is~~ a maximum value matches a central axis of a corresponding light-receiver, and

wherein in a unit pixel, among said unit pixels, which is located at a periphery of the plane, a position at which the effective refractive distribution of a corresponding light-collector represented by the quadratic curve reaches ~~is~~ a maximum value is displaced from the central axis of a corresponding light-receiver toward the center of the plane.

10. (Previously Presented) The solid-state imaging apparatus according to claim 9,

wherein an off-centered light-transmitting film is formed in an area shared by one light-collector and another light-collector in an adjacent unit pixel.

11. (Previously Presented) The solid-state imaging apparatus according to claim 9, comprising:

a first unit pixel for a first color light out of the incident light; and

a second unit pixel for a second color light which has a typical wavelength that is different from a typical wavelength of the first color light;

wherein said first unit pixel includes a first light-collector , and

said second unit pixel includes a second light-collector, in which a focal length of the second color light is equal to a focal length of the first color light in said first light-collector .

12. (Previously Presented) The solid-state imaging apparatus according to claim 9,

wherein a focal point is set at a predetermined position by controlling an effective refractive index distribution of said light-transmitting film.

13. (Previously Presented) The solid-state imaging apparatus according to claim 9,

wherein each of said unit pixels further includes a light-collecting lens on a light-outgoing side of said light-collector .

14. (Previously Presented) The solid-state imaging apparatus according to claim 9,

wherein an effective refractive index distribution of said light-transmitting film is different between light-collectors of said unit pixels located at the center of said plane on which said unit pixels are formed and light-collectors of said unit pixels located at the periphery of the plane.

15. (Cancelled).

16. (Previously Presented) The solid-state imaging apparatus according to claim 9,

wherein each of said plurality of light-transmitting films of one of said unit pixels located near the center of an imaging area has a line width different from a line width of each of said light-transmitting films of one of said unit pixels located at the periphery of the imaging area and is located at a same relative position in said light-collector as a position of each of said light-transmitting films of the one of said unit pixels located near the center of the imaging area, the imaging area being a plane area on which said unit pixels are formed, and

a sum of line widths of said plurality of light-transmitting films of the one of said unit pixels located near the center of the imaging area differs from a sum of line widths of said plurality of light-transmitting films of the one of said unit pixels located at the periphery of the imaging area.

17. (Previously Presented) The solid-state imaging apparatus according to claim 16,

wherein each of said plurality of light-transmitting films of the one of said unit pixels located at the periphery of the imaging area has a line width shorter than a line width of each of said light-transmitting films of the one of said unit pixels located near the center of the imaging area and is located at a same relative position in said light-collector as a position of each of said light-transmitting films of the one of said unit pixels located at the periphery of the imaging area.

18. (Previously Presented) The solid-state imaging apparatus according to claim 9,

wherein each of said plurality of light-transmitting films of one of said unit pixels located at the periphery of an imaging area has a line width shorter than a line width of each of said light-transmitting films of one of said unit pixels located near the center of the imaging area and

is located at a same relative position in said light-collector as a position of each of said light-transmitting films of the one of said unit pixels located at the periphery of the imaging area, the imaging area being a plane area on which said unit pixels are formed.

19. (New) A solid-state imaging apparatus comprising arranged unit pixels, each of which includes a light-collector and a light-receiver,

wherein said light-collector comprises:

a substrate into which incident light is incident; and

above said substrate, a plurality of light-transmitting films are formed in a region into which the incident light is incident,

wherein a light-transmitting film of said plurality of light-transmitting films forms a zone having a width which is equal to or shorter than a wavelength of the incident light,

wherein each zone shares a center point which is located at a position displaced from a center of said light-receiver, and

said plurality of light-transmitting films form an effective refractive index distribution,

wherein, in a unit pixel, among said unit pixels, which is located at a center of a plane on which said unit pixels are formed, a position at which the effective refractive distribution of a corresponding light-collector reaches a maximum value matches a central axis of a corresponding light-receiver, and

wherein, in a unit pixel, among said unit pixels, which is located at a periphery of the plane, a position at which the effective refractive distribution of a corresponding light-collector reaches a maximum value is displaced from the central axis of a corresponding light-receiver toward the center of the plane,

wherein said light-collector further includes zones formed of a pair of a high refractive index material and a low refractive index material, and has a concentric ring structure made up of the zones, and

wherein in each of said unit pixels,

a zone has a same width as a width of a concentrically-formed outer zone, and

a width of the high refractive index material of the zone is wider than a width of the high refractive index material of the concentrically-formed outer zone.

REMARKS

Initially, Applicant wishes to thank the Examiner for the detailed Office Action. Applicant would also like to thank the Examiner for conducting a telephone Interview with Applicant's Representative, Monica S. Ullagaddi, on March 16, 2010. In this regard, Applicant's Representative and the Examiner discussed whether the present application would be allowed if new claims (set forth in the Response Under 37 C.F.R. §1.116 dated February 16, 2010) were cancelled and a new Terminal Disclaimer were filed. However, the Examiner indicated that the present application would require further search and consideration. No agreement was reached.

In the outstanding Office Action, claims 2-5, 9-14 and 16-18 stand rejected under 35 U.S.C. §103(a) as being unpatentable over MEYERS (EP 0809124) in view of HUANG et al. (U.S. Patent Application Publication No. 2003/0044729). Claims 6-8 stand rejected under 35 U.S.C. §103(a) as being unpatentable over MEYERS in view of HUANG et al. in further view of DELLWO et al. (U.S. Patent No. 7,390,532).

Upon entry of the present amendment, independent claim 9 will have been amended and new independent claim 19 will have been added. The amendments to independent claim 9 and the addition of new independent claim 19 should not be considered an indication of Applicant's acquiescence as to the propriety of any of the outstanding rejections. Rather, Applicant has amended independent claim 9 and added new independent claim 19 solely to advance the prosecution and to obtain an early allowance of the claims in the present application, as well as to afford Applicant the scope of protection to which he is entitled for the disclosed invention.

Applicant respectfully traverses the outstanding rejections. It is a design objective of digital cameras to minimize the thickness of the camera. By shortening the focal length of an

optical system of an imaging lens is one manner in which the thickness of a digital camera is decreased. However, since light incident on the periphery of a solid-state imaging apparatus such as a charge-coupled device (CCD) or metal oxide semiconductor (MOS) sensor enters at an oblique angle with respect to the vertical axis of the surface of incidence, sensitivity significantly deteriorates at the periphery. To address the above-noted issue, according to one non-limiting embodiment of the presently claimed invention, the refractive indices of light-transmitting films are modulated by forming light transmitting films each having a combination of concentric zones, each of which in turn, has an arbitrary line width that is equal to or shorter than the wavelength of incident light. More particularly, effective refractive index distribution lenses having independently variable refractive index distributions for each pixel of the solid-state imaging apparatus are provided. Thus, incident light is refracted due to the position-dependent effective refractive index of the claimed light-collector.

To further elucidate the above-noted features of Applicant's independent claim 9, FIGS. A and B are provided herein. In both FIGS. A and B, shading in the illustrated effective refractive index distribution lens represents variation in a refractive index, and a density of shading represents the level of refractive index. FIG. A illustrates light collection by an effective refractive index distribution lens having *a symmetric effective refractive index distribution*. The wavefront (*i.e.*, a surface having the same phase) of light incident in the vertical direction is shown as a solid line. The refractive index is inversely proportional to the distance traveled by light; that is, the wavefront of the light passing through the effective refractive index distribution lens is curved and light is collected at the light-receiver. FIG. B illustrates light collection by an effective refractive index distribution lens having an *asymmetric effective refractive index distribution*. That is, the density of shading is shown as *being at the left of the effective*

refractive index lens, and not at the center of the effective refractive index lens, as in FIG. A. The wavefront of light incident at an incidence angle θ with respect to the vertical direction is shown with a solid line. The wavefront of the light passing through the asymmetric effective refractive index distribution lens is curved as shown in FIG. B and the light is also collected at the light-receiver.

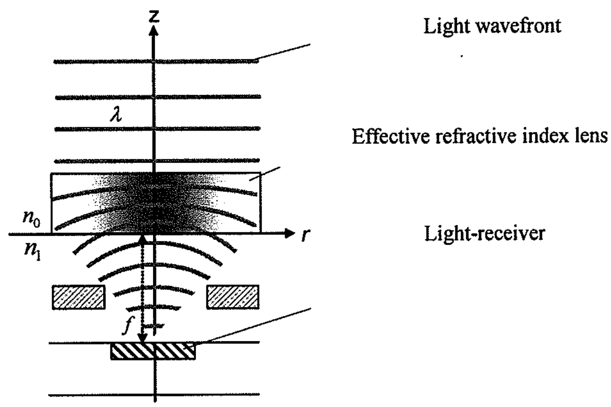

FIG. A

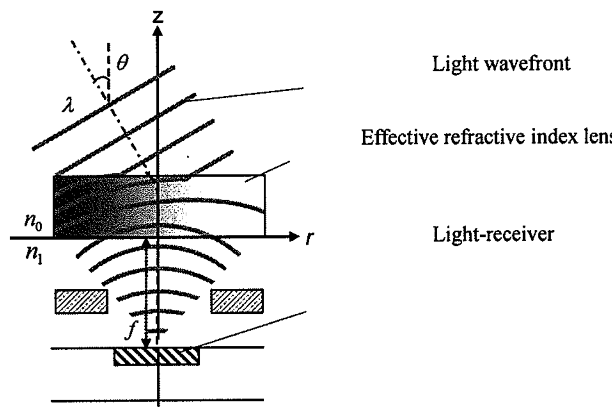

FIG. B

In the claimed solid-state imaging apparatus, in each of the light-collectors in the claimed arranged unit pixels, the center of the zones is a position at which an effective refractive index distribution of a corresponding light-collector represented by the quadratic curve reaches a maximum value matches a central axis of a corresponding light-receiver. That is, the maximum value of the quadratic curve representing the effective refractive index distribution shifts toward the center of the sensor on the light incoming side as the incidence angle of incident light increases. As shown in FIGS. A and B above, an increasing incidence angle results in a shift of the maximum value of the effective refractive index distribution from the center (*i.e.,* as shown in FIG. A) to the left (*i.e.,* as shown in FIG. B) of the claimed solid-state imaging apparatus. Thus, an optimal effective refractive index distribution is achieved for each unit pixel, which allows each unit pixel located at the periphery of the claimed solid-state imaging apparatus to efficiently collect incident light and achieve the same sensitivity as is achieved by pixels at the

center of the claimed solid-state imaging apparatus, even when light is incident obliquely and with a large angle of incidence with respect to a axis transverse to the surface of incidence. *See, e.g.,* FIG. B illustrated above. Accordingly, the presently claimed invention implements a solid-state imaging apparatus that eliminates differences in light-collection efficiency due to an increase in an angle of incidence of incident light, and which has high sensitivity as well as high sensitivity uniformity.

The Examiner asserts MEYERS as teaching arranged unit pixels, a light receiver, a substrate onto which the incident light is incident, and a plurality of light transmitting films formed in a region in which the incident light is incident above the substrate, as specified in independent claim 9. The Examiner also asserts that a light-transmitting film that forms a zone in which a width of each zone is equal to or shorter than a wavelength of the incident light is inherently present in MEYERS. However, the Examiner also acknowledges that MEYERS fails to disclose that each zone shares a center point which is located at a position displaced from a center of said light-receiver, as recited in Applicant's independent claim 9. The Examiner asserts HUANG et al. as teaching the above-noted features of Applicant's independent claim 9. The Examiner also asserts HUANG et al. as teaching that, in a unit pixel, among said unit pixels, which is located at a center of a plane on which said unit pixels are formed, a position at which an effective refractive distribution of a corresponding light-collector is a maximum value matches a central axis of a corresponding light-receiver; and in a unit pixel, among said unit pixels, which is located at a periphery of the plane, a position at which the effective refractive distribution of a corresponding light-collector is a maximum value is displaced from the central axis of a corresponding light-receiver toward the center of the plane.

Applicant's amended independent claim 9 recites that, *inter alia,* a plurality of light-

transmitting films form an effective refractive index distribution *represented by a quadratic curve expressed by a distance from a center of a corresponding one of the unit pixels*. Applicant's amended independent claim 1 also recites, *inter alia,* in a unit pixel, among said unit pixels, which is located at a center of a plane on which said unit pixels are formed, a position at which *an effective refractive index distribution of a corresponding light-collector represented by the quadratic curve reaches a maximum value matches a central axis* of a corresponding light-receiver, and in a unit pixel, among said unit pixels, which is located at a periphery of the plane, a position at which *the effective refractive distribution of a corresponding light-collector represented by the quadratic curve reaches a maximum value is displaced from the central axis* of a corresponding light-receiver toward the center of the plane.

Applicant respectfully submits that HUANG et al. discloses a method of forming a diffractive light-collector for each pixel of an image sensor. The asserted portions of HUANG et al. in FIGS. 2C and 3 are submitted to illustrate a phase grating lens 212 formed in a flattening layer 208. HUANG et al. is further submitted to disclose that each phase grating lens 212 is used to focus the incident light beam on the photosensitive device 202, (and) therefore the depth of the phase grating lens 212 and the radius of each concentric circular trench depend on where the focus is desired to be located.

However, Applicants respectfully submit that the center points of the concentric circles shown in FIG. 3 of HUANG et al. are not displaced. In contrast to the teachings of HUANG et al., each of the claimed light-collectors collects light through a difference in refractive index by achieving *a symmetric or asymmetric effective refractive index distribution* (depending upon location) through a corresponding light-transmitting film having an arbitrary line width equal to or shorter than the wavelength of incident light. Each of the claimed light-collectors forms an

optimal effective refractive index distribution for a corresponding unit pixel by *shifting the maximum value of a quadratic curve representing the effective refractive index distribution toward the center of the sensor on the light incoming side*. Therefore, Applicants respectfully submit that HUANG et al. fails to disclose or render obvious at least the above-noted features of Applicant's independent claim 9.

Applicant respectfully submits that MEYERS also fails to disclose or render obvious the recited features of Applicant's independent claim 9. Applicant respectfully submits that MEYERS is directed to a structure in which downwardly-convex lenses and apertures are positioned off-center with respect to pixels at the periphery of an image sensor having an array of light-receiving devices. The downwardly-convex lenses and apertures become increasingly off-centered in an outward direction from the center of the image sensor. Even assuming, *arguendo,* that MEYERS is properly interpretable as disclosing receiving incident light at the periphery of the image sensor, MEYERS is submitted to disclose that the *lenses have a variable shape* depending on the pixels, but that *the material has a uniform refractive index*, *and not* that the refractive index of the lens varies, depending on the pixels, as recited in Applicant's independent claim 9. Accordingly, Applicant respectfully submits that MEYERS fails to disclose or render obvious at least the above-noted amended features of Applicant's independent claim 9.

In view of the above, Applicant respectfully submits that the combination of MEYERS and HUANG et al. set forth by the Examiner fails to disclose or suggest at least the above-noted recited features of Applicant's independent claim 9 and thus, Applicant's independent claim 9 is allowable over MEYERS in view of HUANG et al.

Further, each of dependent claims 2-8 and 10-18 are submitted to be allowable at least because they depend from independent claim 9, which Applicant submits has been shown to be

allowable. Each of dependent claims 2-8 and 10-18 are also submitted to recite further patentable subject matter.

With respect to the 35 U.S.C. §103 rejection of claims 6-8, it is submitted that DELLWO fails to cure the deficiencies of MEYERS in view of HUANG et al. noted above with respect to independent claim 9, from which claims 6-8 depend, nor is DELLWO applied to cure the above-noted deficiencies. As such, allowance of dependent claims 6-8 is submitted to be proper for at least the same reasons noted above for independent claim 9, upon which they depend, in addition to reasons related to their own recitations.

In view of the above, reconsideration and withdrawal of the rejection of claims 2-5, 9-14 and 16-18 under 35 U.S.C. §103(a) as being unpatentable over MEYERS in view of HUANG et al.; and the rejection of claims 6-8 under 35 U.S.C. §103(a) as being unpatentable over MEYERS in view of HUANG et al. in further view of DELLWO et al. is respectfully requested.

New independent claim 19 is submitted herewith for the Examiner's consideration. Applicant respectfully submits that new independent claim 19 is allowable at least for reasons set forth above with respect to independent claim 9, in addition to reasons related to its own recitations. For example, none of MEYERS, HUANG et al. and DELLWO et al., either singularly or in any proper combination, disclose or render obvious at least that each zone shares a center point which is located at a position displaced from a center of said light-receiver, as recited in independent claim 19. Further, none of MEYERS, HUANG et al. and DELLWO et al., either singularly or in any proper combination, disclose or render obvious that in a unit pixel, among said unit pixels, which is located at a center of a plane on which said unit pixels are formed, a position at which the effective refractive distribution of a corresponding light-collector reaches a maximum value matches a central axis of a corresponding light-receiver, and, in a unit

pixel, among said unit pixels, which is located at a periphery of the plane, a position at which the effective refractive distribution of a corresponding light-collector reaches a maximum value is displaced from the central axis of a corresponding light-receiver toward the center of the plane, as recited in independent claim 19.

Should an extension of time be necessary, the Commissioner is hereby authorized to charge any additional fee to Deposit Account No. 19-0089.

Should the Examiner have any questions concerning this Response or the present application, the Examiner is respectfully requested to contact the undersigned at the telephone number listed below.

Respectfully Submitted,
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